Goals

The first 24 hours

How to deliver the best Pre-hospital, Emergency and ICU care to patients with Traumatic Brain Injury

Traumatic Brain Injury (TBI)

• TBI is the leading cause of death and disability in children & young adults
Mechanisms of Injury

Primary Injury
-- At the moment of impact
- Mechanical
- Vascular
- Cellular

Secondary Injury

Not all neurological damage from TBI occurs at the moment of impact

Management of Secondary Injury

- Secondary injury is preventable
- Secondary injury is treatable
Prehospital TBI Management

How we make a difference
• Timing & transport
• Brain metabolism – O2
• Cerebral perfusion – BP
• Raised intracranial pressure

Transport Decisions

❖ All regions should have:
❖ Protocols to direct EMS personnel
❖ An organized trauma care system

Timing

Field Stabilization versus Scoop & Run
• Needs to be individualized
• Anticipated time to destination
• Destination –
• Severity of the TBI
In general, Quality of resuscitation in the field impacts outcome more than speed
Oxygenation: Pre-hospital Guidelines

1. Measure SaO2 with pulse oximeter continuously
2. Provide supplemental O2
3. Keep SaO2 > 90%

Pre-hospital Guidelines: Hypoxia

Intubate patients with:
1. Persistent hypoxemia (sat <90%) not corrected by supplemental O2
2. Inability to maintain an adequate airway
   - Apnea
   - Airway compromise
   - Unconsciousness or unresponsiveness with GCS< 8
   - Cough & gag reflexes can raise ICP
   - Orotracheal > nasotracheal

Guidelines Blood Pressure – Level II

Blood Pressure
- Avoid hypotension
  - sBP < 90 mmHg
- Isotonic saline
- Fluid resuscitation a balance:
  - Maintain cerebral perfusion ↔ avoid fluid overload, osmotic shifts, brain edema
TBI Management in the ED

Intracranial Pressure (ICP)

ICP = Brain + CSF + Blood vascular volume + Mass Lesion

Raised Intracranial Pressure

Cerebral Herniation
Hyperosmolar Therapy

MANITOL

Level III
- Prior to ICP monitoring, restrict mannitol use to patients with signs of impending cerebral herniation.

Level II
- Mannitol (1.0-1.4 gm/Kg)
- Avoid arterial hypotension

When to hyperventilate?

Hyperventilation
- CO2 causes relaxation of vascular smooth muscles of arterioles and decreased vascular resistance

<table>
<thead>
<tr>
<th>Goal impending herniation</th>
<th>pCO2 32-35</th>
<th>Not &lt;30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal (breaths/min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adults</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>children</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Hyperventilation (breaths/min)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When is it OK to Hyperventilate?

Options
- Brief hyperventilation for acute deterioration secondary to raised ICP
- Avoid prophylactic hyperventilation (PaCO2 ≤ 35 mmHg) during first 24 hours
  * can compromise cerebral perfusion during a time when cerebral blood flow (CBF) is reduced
**TBI Management in the ICU**

**Who Needs ICP Monitoring?**

Primary indication for ICP monitoring:
- absence of a neurological exam that can be followed

**Guideline**

GCS ≤ 8

With Abnormal CT scan

- or

Normal CT scan with
  - age > 40
  - unilateral or bilateral posturing
  - systolic pressure < 90 mmHg

**ICP Monitoring**

**Guideline**

ICP Treat for threshold > 20mmHg
Optimize Factors Affecting ICP

- **pCO2**
  - Maintain 35-45mmHg; goal 40mmHg

- **Fluid status**
  - CVP goal 5-7mmHg

- **Sodium level**
  - 135-145; goal 140

- **Positioning**
  - HOB 45 degrees;
  - Neck straight
  - Loosen C-collar
  - Relieve abdominal compression

- **Temperature**
  - ≤ 37.5°C; goal 37.0

- **Agitation**

ICP Directed Therapy

Outcomes in Relation to ICP

<table>
<thead>
<tr>
<th>ICP Status</th>
<th>No of cases</th>
<th>Good/Moderate disability (%)</th>
<th>Severe/Vegetative (%)</th>
<th>Dead (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal (10-20mmHg)</td>
<td>91</td>
<td>74</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>Raised but reducible</td>
<td>74</td>
<td>55</td>
<td>19</td>
<td>26</td>
</tr>
<tr>
<td>Not reducible</td>
<td>31</td>
<td>3</td>
<td>3</td>
<td>92</td>
</tr>
</tbody>
</table>

Miller and Becker 1981
Why isn’t ICP monitoring enough?

- Compliance
- Cerebral Blood flow
- Autoregulation
- Oxygenation
- Metabolism
- Function

Multi-Modal TBI Monitoring

1. Reactivity challenges - autoregulation
2. Jugular venous sat’n
3. Brain Tissue O2
4. Cerebral blood flow

Pressure Reactivity Challenges

- Is cerebral autoregulation intact?
ICP Monitoring

CPP = MAP – ICP
Guideline
- Avoid aggressive attempts to maintain CPP > 70 with fluids & pressors
- Increased risk of ARDS

Cerebral Autoregulation
CBF remains constant as blood pressure varies

Pressure Reactivity Testing
Autoregulation challenge
Goal Map: 10-15 mmHg above baseline
- Use neosynephrine increase 20ug/min q 5min to goal MAP; Endpoints ICP, CPP and CBF
Cerebral Autoregulation and TBI

- Reactivity index - MAP/ICP slope
  - Cut-off is 0.13
  - 15mmHg increase MAP leads to 2mmHg increase in ICP

Howells et al. JNS 2005

Jugular Venous Saturation

- Global measure of cerebral metabolism:
- Measures total venous brain tissue oxygen in jugular bulb
- Compare to arterial line pO2
- Oxygen extraction by the brain

Normal

- SjvO2 ~ 75%

Guideline

- Treatment Threshold SjVO2 < 50%
### SjVO2

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal values</td>
<td>75%</td>
</tr>
<tr>
<td>Critical values</td>
<td>&lt; 50</td>
</tr>
<tr>
<td>Hypoxia</td>
<td>Decreased</td>
</tr>
<tr>
<td>Increased O2 demand (seizures, fever, agitation)</td>
<td>Decrease due to increased extraction</td>
</tr>
<tr>
<td>Global Decrease CBF (hypotension, hypovolemia, ischemia)</td>
<td>Decreased</td>
</tr>
<tr>
<td>Hyperemia</td>
<td>Increase</td>
</tr>
<tr>
<td>Irreversible injury</td>
<td>Increase</td>
</tr>
</tbody>
</table>

### Brain Tissue Oxygen Monitor \( P_{brO_2} \)

- A closed polarographic probe with reversible electrochemical reactions

### Brain Tissue Oxygen

- Brain O2 probes placed in white matter
- Normal values for white matter 20-30mmHg
Cerebral Blood Flow

- Less than 1 mm diameter flexible probe

Thank you

San Francisco General Hospital & Trauma Center